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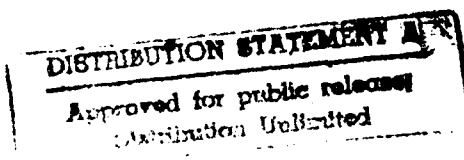
EMBEDDED COMPUTER  
SYSTEMS

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Status of C-17 Software

Statement for the Record by  
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Mr. Chairman and Members of the Subcommittee:

I am pleased to submit this statement for the record as part of the Subcommittee's hearings on the C-17 aircraft program. As you know, the C-17 will be the most computerized, software-intensive, transport aircraft ever built. Embedded computers are essential for the C-17 to accomplish its mission--the aircraft depends on these computers to control basic avionics functions such as flight control, communication, and instrument displays. The C-17 relies on 19 different types of embedded computers incorporating over 80 microprocessors and about 1.3 million lines of code. This statement provides information on the current status of embedded computer and software development for the C-17.

In summary, we have observed a pattern of the Air Force continuing to permit its prime contractor, McDonnell Douglas Corporation, to defer software development to future aircraft. Originally, the first aircraft (T-1), delivered in September 1991, was supposed to include all the software. But, McDonnell was unable to develop and deliver the software on time. Rather than slowing aircraft production until the software could be completed, McDonnell deferred software development, initially to the P-2 aircraft, then to the P-5 aircraft, and now to the P-6 and future aircraft. Each software development deferral further delays the Air Force's ability to fully test the software and demonstrate that the C-17 can meet all of its requirements.

The Air Force is continuing to experience embedded computer and software development problems on the C-17 in three major areas. First, some critical software functions are either still being developed or are incompletely tested. Although McDonnell has made substantial progress in the past year, software immaturity still prevents the C-17 from meeting critical mission requirements and severely limits testing. Secondly, McDonnell continues to have problems in meeting reserve processing and memory capacity requirements. The C-17's embedded computers need this reserve capacity to service future growth, but the Air Force continues to waive these requirements to minimize schedule delays. Lastly, McDonnell has still not developed adequate system documentation, thereby jeopardizing the Air Force's ability to efficiently test, maintain, and upgrade C-17 computer systems.

#### BACKGROUND

In May 1992 we reported that the C-17 faced significant software development problems.<sup>1</sup> The Air Force made a number of major

<sup>1</sup>Embedded Computer Systems: Significant Software Problems on C-17 Must Be Addressed (GAO/IMTEC-92-48, May 7, 1992).

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mistakes early in the program that affected its ability to manage and oversee software development. Air Force officials initially assumed that software was a low-risk part of the C-17 program and, therefore, did not adequately manage its software development. In addition, McDonnell and its subcontractors used software to solve several aircraft design and performance problems, further complicating the development effort. The Air Force also found that they lacked specific knowledge about software problems when they first occurred, and did not ensure that McDonnell took timely corrective action. Thus, we concluded that the C-17 program was a good example of how not to manage software development when procuring a major weapons system.

We also reported that because of problems and delays in developing and testing software and the lack of quality system documentation, McDonnell (with the Air Force's concurrence) took a number of shortcuts to minimize schedule delays. For example, McDonnell delayed the completion and installation of most mission-critical software functions, such as navigation and communications, until the second production aircraft (P-2)--the avionics test aircraft. According to the original C-17 full-scale development contract, the first test aircraft (T-1) was to include all of the software. The Air Force also "temporarily" waived reserve processing and memory capacity requirements for several of the most critical computers, including the mission computer and multifunction display, on the first five aircraft. Past experience on major Defense software development efforts clearly shows that taking shortcuts like these and not solving problems promptly greatly complicates and makes more costly the effort required to make the software function correctly.

In our May report we endorsed Congressional direction that Defense perform and submit an independent "Early Operational Assessment" of the C-17's mission capabilities following completion of the first 50 hours of operational flight test. We also recommended that the Secretary of Defense expand this assessment to evaluate (1) the impact of software risks on the C-17 development and flight test program, and (2) Air Force plans to ensure adequate preparation and approval of software support documentation. As discussed below, Defense evaluated software deficiencies and documentation as part of its Early Operational Assessment.

#### EARLY OPERATIONAL ASSESSMENT

In its December 1992 Early Operational Assessment of the C-17, the Defense Director of Operational Test and Evaluation concluded that immature software has limited testing of the C-17's operational capabilities, such as flight controls, stall warning, communications, aerial delivery, and navigation. These software shortfalls are now affecting the C-17's readiness for operational testing, which was expected to start in September 1993. This testing has now been delayed until January 1994. In addition, the

Director concluded that software documentation is not adequate, and without quality documentation, the Air Force's ability to carry out its software maintenance activities may be impaired. This assessment further substantiated the software problems we reported to you in May 1992.

#### CURRENT STATUS

The C-17 is still plagued with many of the same software development problems we identified last year. McDonnell has still not delivered an aircraft with a fully functional avionics suite, although it has added much of the missing functionality through a series of software upgrades.

When serious software development problems led to schedule slippage early in the program, McDonnell revised its plans. It concentrated its development efforts on those basic avionics functions needed for initial flight testing of the T-1 aircraft, but required that all subsequent aircraft be 100 percent functional. This approach provided the software needed to ensure that the T-1 aircraft could safely take-off, demonstrate basic flying qualities, and land. It also allowed McDonnell to delay development and testing of the software needed for more sophisticated avionics functions until delivery of the P-2 aircraft.

The P-2 aircraft, which was delivered to the Air Force in June 1992, about six months late, was designed to contain the specialized instruments (not included on any other C-17 aircraft) needed to measure and record C-17 avionics test results. However, when the aircraft was delivered, it contained only 55 percent of the mission computer's required software and 80 percent of the electronic flight control and communication software. Again, McDonnell continued its software development and improvement efforts, while planning to install the missing software on future aircraft. However, it was understood that any software delivered on future aircraft would have to be installed and retested on the P-2 aircraft, which would, in turn, stretch out the test program.

The P-5 aircraft, delivered to the Air Force a few days ago on March 12, 1993, still does not contain all required software. Most significantly, the electronic flight control system does not have the software needed to perform take-offs and landings on short airfields and low-altitude parachute drops, two key mission requirements. In addition, the mission computer does not have the required software for critical flight and navigation maneuvers, such as flying in formation and joining other aircraft at selected geographical positions. The Air Force granted what it calls "temporary" relief from these software requirements to maintain the P-5 delivery date, which is critical to the release of additional funding for the C-17 program.

According to the C-17 program office, McDonnell is planning to install some of the remaining missing software on the P-6 aircraft, expected for delivery in June 1993. However, McDonnell does not expect to have some required software until March 1994--the planned delivery date for P-11. And, consistent with past performance, the program office expects McDonnell to seek a new waiver for software that may not be developed by this date.

McDonnell also remains unable to meet reserve processing and memory capacity requirements. The C-17 contract specified that 25 to 40 percent of the memory and processing capacity of the computers that operate C-17 avionics and flight control subsystems had to be reserved to meet future needs. Six major subsystems, including the mission computer and multifunction display, do not meet these requirements. As it has done when faced with software problems in the past, the Air Force has temporarily waived reserve capacity requirements for these subsystems, not only for P-5, but for later production aircraft as far out as P-13, expected to be delivered in June 1994. If computer reserve capacities cannot be restored, the Government has two options: grant permanent relief, thereby accepting the aircraft with less capacity than originally required or require McDonnell to replace the C-17 computer processors that are not meeting specifications.

Finally, the Air Force's ability to test, maintain, and upgrade C-17 computer systems is in jeopardy because McDonnell has still not developed adequate system documentation. Without good documentation, a computer system is difficult to understand and maintain, and there is less assurance that system modifications will function as required. In the past, organizations have chosen to redesign and rebuild systems because poor documentation made an existing system too difficult to understand and modify. For those avionics subsystems the Air Force plans to maintain, less than half of the required documents have been approved to date.

The Air Force is planning to partially maintain the C-17 at the San Antonio Air Logistics Center. However, without adequate documentation, it cannot effectively establish this "in-house" capability and will have to rely more on McDonnell or the subcontractor who built the subsystem to provide software support.